X-614-67-42

NASA TM X- 55768

GROUNDING OF ROCKET EXPERIMENTS

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FEBRUARY 1967

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This paper describes some of the points to be considered in the design and construction of an experiment to make it compatable with, and immune to the noise from, the rocket and pointing control on which it is flown. The discussion will be primarily concerned with the Aerobee rocket equipped with a Ball Brothers Corporation Solar Pointing Control, but the points covered apply to all other systems as well.

Prior to the discussion of rockets and their specific problems, it may be useful to look at an amplifier circuit and the problems of grounding encountered. Figure 1 is a block diagram of an amplifier connected to a detector and a power source. Included are the various impedances between the separate points around the amplifier, which illustrate the many paths by which noise can be introduced into the amplifier. The chassis commons shown in the figure do not necessarily represent conductive connections but may actually be capacitive reactances between the various circuit components in the proximity to the chassis. This figure shows why, because of the many possible chassis noise signal paths, it is sometimes difficult to eliminate noise from an improperly connected amplifier. In general, impedances Z1, Z2, Z3, Z5, Z6, Z7, Z8, and Z9 should be made as small as possible and impedances Z4 and Z10 should be made as large as possible. Taking these precautions will at least insure that whatever noise currents that do flow on the chassis will produce small noise signals in the amplifier.

The most important points to note in this figure are the location of the termination of the experiment power supply common and the value of impedance Z5. As an illustration of what can happen in an improperly connected amplifier, suppose the power supply common is connected to point J in figure 1. Also assume that there is a noise voltage (a-c ripple voltage) on the D.C. voltage input wire that is to be filtered by decoupling network R and C1. It is obvious that the noise current pulse, through capacitor C1, must flow back to the power supply common via impedance Z5 and just as obvious that the resulting voltage drop will be impressed across the amplifier input. In other words, for a given value of ripple noise voltage and capacitance C1, the smaller the magnitude of impedance Z5, the smaller the magnitude of the noise signal that will result.

As another example, consider the power supply common. This common, unfortunately for the experiment, is generally connected to the rocket frame at a point far removed from the chassis of the experiment. If the experiment does not have an isolating power supply to break this path, a chassis ground loop will be introduced through impedances Z1, Z7 and Z5 and any noise pulse currents on this path will cause noise signals to be introduced into the amplifier. This same arguement holds true for the high voltage supply which should also be isolated.

If you study figure 1 you will find other similar instances of ways that noise can be introduced into the amplifier.

The isolating supply mentioned in the above paragraph has proved to be one of the most useful methods of reducing the noise that is fed into a circuit. The purpose of the supply is to break the conductive path in both the positive current carrying wire and the common line, between the primary source of D.C. power and the circuitry that operates from it. This is usually done through the use of a transformer and associated circuitry. One indication of the worth of such a device is the following. A camera exposure timer was built with an isolating supply as a part of the circuitry. When the common lines in the primary and secondary of the transformer were shorted together and noise was fed to the common at the point of the D.C. source the timer reacted to current pulses of about 200 milliamps. With the short removed, the circuit failed to react to 5 ampere pulses. From this it is obvious that this type of supply should be used whenever and wherever possible.

Past experiments have included cameras, with electrically operated film transports and shutter mechanisms, together with electrometers and proportional counter electronics. The Solar Pointing Control (SPC) includes low power circuits for amplifying signals from silicon solar cell "eyes" and high power motors for controlling the azimuth and elevation of the experiment in relation to the sun. In each there are noise producing elements, the carmeras in the experiment and the motors in the SPC; and circuits which are vulnerable to the noise being produced, the electrometers and proportional counter electronics in the experiment and the solar cell amplifiers in the SPC. Each of these elements must be taken into account when an experiment is being designed and built.

The first and most obvious step to be taken is to eliminate all of the sources of noise wherever possible, because the best designed circuitry will react to noise if it is of sufficient amplitude. One such source of noise is the pulse voltage that is produced by a relay coil when the relay is deenergized and the magnetic flux in the core suddently reverses. This source of noise can be eliminated by placing a diode across the coil of the relay. This diode will conduct when the voltage reverses across the coil and prevent the voltage from rising above the forward drop of the diode. Relays not so protected can produce voltage pulses on the order of 600 volts. Pulses of this magnitude have been known to couple into the experiment, via the baseplate, with sufficient energy to trigger flip-flops inside the package.

The point of chassis ground for the experiment should be at only one point, and this point should be physically located as close as possible to the most sensitive amplifier in the experiment. All other returns from the different portions of the experiment, including the battery return, should be brought to this point on separate wires. There are exceptions to this rule, in that high pulse currents should not be allowed to flow on the chassis, or more important, on the commons of the other circuits in the experiment. Therefore devices such as motors, solenoids, calibrators, etc, should be returned directly to the D.C. source, and on separate wires. If it is impossible to use separate wires for the returns of the various circuits, then at least all low level circuits must be returned on a single wire separate from the high level returns. These precautions are necessary because the impedance of the wire, even though small, acts as a voltage source when current flows through the wire. The resulting voltage can act as a signal or bias for any sensitive circuit connected to it.

In the past it has been the practice to have the shields of the experiment and the pointing control tied to a common return. A better practice is to provide separate returns for the experiment and pointing control shields to prevent coupling between the experiment and the pointing control on this shield return. The shield returns should be brought to the point where the telemetry transmitter goes to the chassis. Past performance has not indicated that the common return for the shields has caused the loss of data, but since these wires carry pulsing currents, and run on the outside of the package where they are exposed to RF, it is best to separate them before trouble does occur and valuable scientific data is lost.

In these Aerobee rockets, a part of the experiment is supported by a pivitol bearing in the pointed section of the vehicle. The chassis return for this section should not go through the variable and unknown resistance of this bearing, but should be returned through a separate wire. This wire should go directly from the chassis ground point in the experiment to the point where the pointing control power source goes to the chassis in another section of the payload. If the number of wires available is greatly limited, the experiment shield return, discussed in the preceding paragraph, and this chassis return can be returned on the same wire. This has been done in the past and no great difficulty has been experienced. But, these returns should never be returned via the pointed control power or signal returns. If the experiment chassis or shield were so returned, it is possible for noise to be fed from the experiment to the pointing control, or vice-versa.

Post flight tests on the experiment and pointing control flown on Aerobee's 4.53 and 4.145, indicate that noise generated in the experiment and coupled into the pointing control caused the pointing control to fail. Figure 2 is the grounding system that was used on these rockets. It will be noted that the chassis return for the experiment was returned on the pointing control power return, and that the noise generated in the experiment camera motor is impressed on the return of the solar cell "eye" amplifier. This noise appeared to the pointing control as a signal from the "eyes" and the pointing control tried to obey this erroneous signal. The result was that the pointing control was driven away from the sun and respun with the rocket body. Tests prior to the flight were conducted at atmospheric pressure and there were no indications of abnormal operation. These tests are normally run at atmosphere, so it is obvious that in all future ventures, it is necessary to take all of the precautions possible to reduce noise to prevent a recurrence of these failures.

Noise coupling between wires in a bundle can be reduced by twisting in pairs, the positive current carrying wire with its associated return. This twisting in pairs causes a cancellation of the magnetic field about the wire, created by the current flowing through it, and thereby greatly reduces the coupling.

Figure 3 shows in block form, the grounding system used on Aerobee's 4.95 and 4.153 which were successfully flown in April and November 1966. This system is an example of the above thinking and one which operated satisfactorily. Noise on the signal lines was well within the noise limits of the telemetry and recording devices used on the flight.

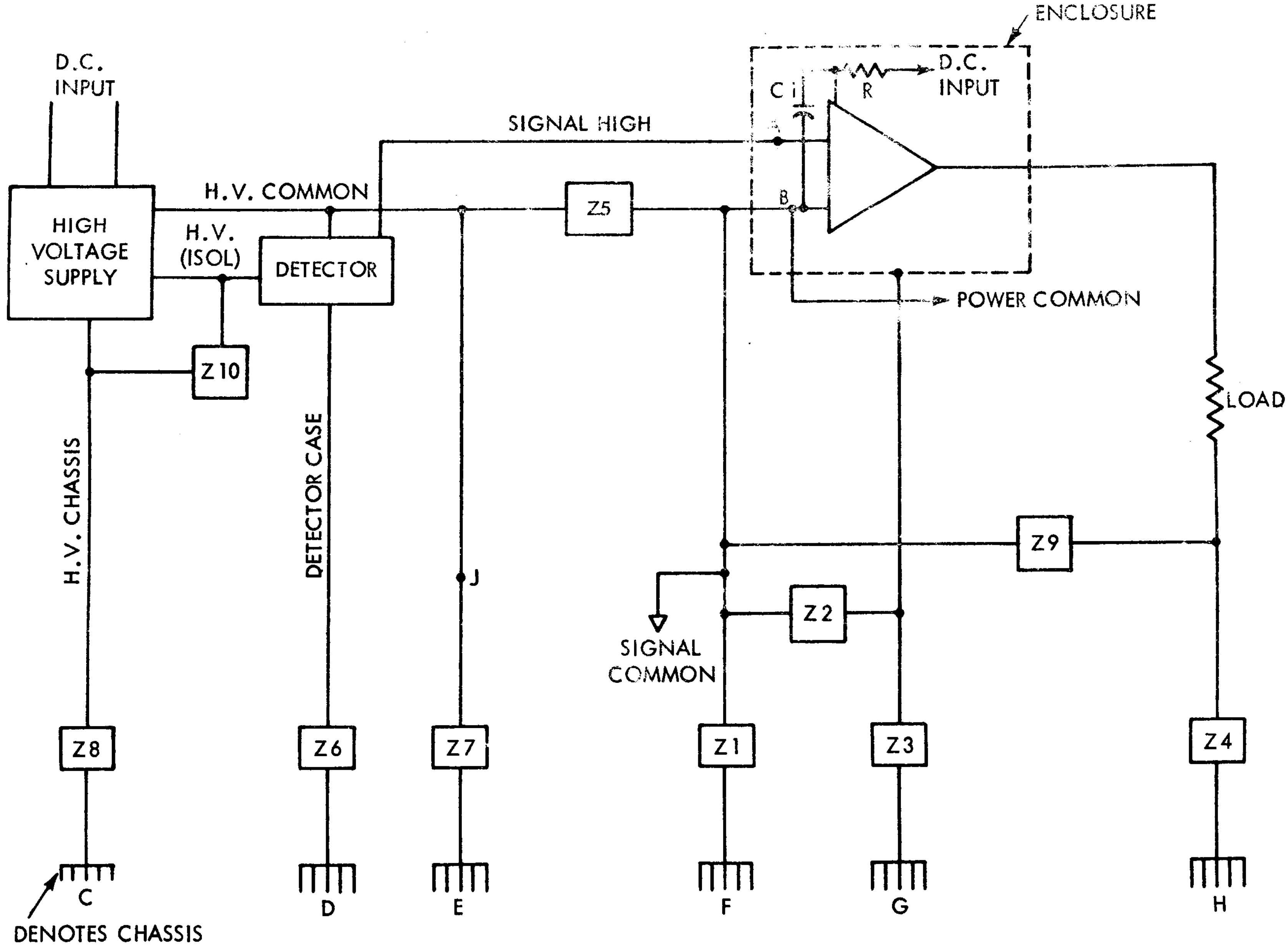
In brief, the following points should be observed in the design and construction of an experiment.

1. Connect the experiment power supply common to the lowest level amplifier.
2. Connect all amplifier commons together with a flat braid. (Low inductance strap)
3. Use isolation power supplies wherever possible.
4. Isolate the signal inputs and outputs.
5. Electrically isolate the experiment chassis.
6. Do not allow current from pulsed electro-mechanical devices to flow on the chassis or return lines.
7. Provide isolated conductive paths (separate wires for the power and common) for all pulsed devices within the experiment (stepping motors, calibrators, relays, etc).
8. Do not connect any returns from the experiment to those of the pointing control.

Testing of the experiment and pointing control to detect and/or locate sources of noise interference is a time consuming and costly procedure. This is due to the fact that some sources of noise do not generate enough noise at atmospheric pressure to cause trouble, but under the reduced pressures encountered in flight their output can increase enough to cause a failure. It is therefore necessary to test the pointing control, with the experiment mounted, in a vacuum. However, these pointing controls are not made to withstand long periods of vacuum. This necessitates the modification of the pointing control to enable it to operate in a vacuum and to return it to flight configuration after the testing is completed. A vacuum chamber must be located that will accept the pointing control with the experiment mounted. A unit of this size is not always readily available, and is expensive to operate. From this it is obvious that the expense and time involved make it desirable to eliminate this testing. It can be, and a high degree of probable success maintained, if the principles of this paper, and a lot of thought is put into the grounding of the experiment- pointing control combination.

ACKNOWLEDGEMENT

The author wishes to acknowledge the assistance of Mr. Joseph C. Thornwall in the compiling and editing the material contained in this paper.


ENCLOSURE
D.C. INPUT
HIGH VOLTAGE SUPPLY
H.V. COMMON
H.V. (ISOL)
DETECTOR
SIGNAL HIGH
C i
R
D.C. INPUT
A
B
POWER COMMON
LOAD
Z5
Z10
Z9
Z2
H.V. CHASSIS
DETECTOR CASE
J
SIGNAL COMMON
Z8
Z6
Z7
Z1
Z3
Z4
C
D
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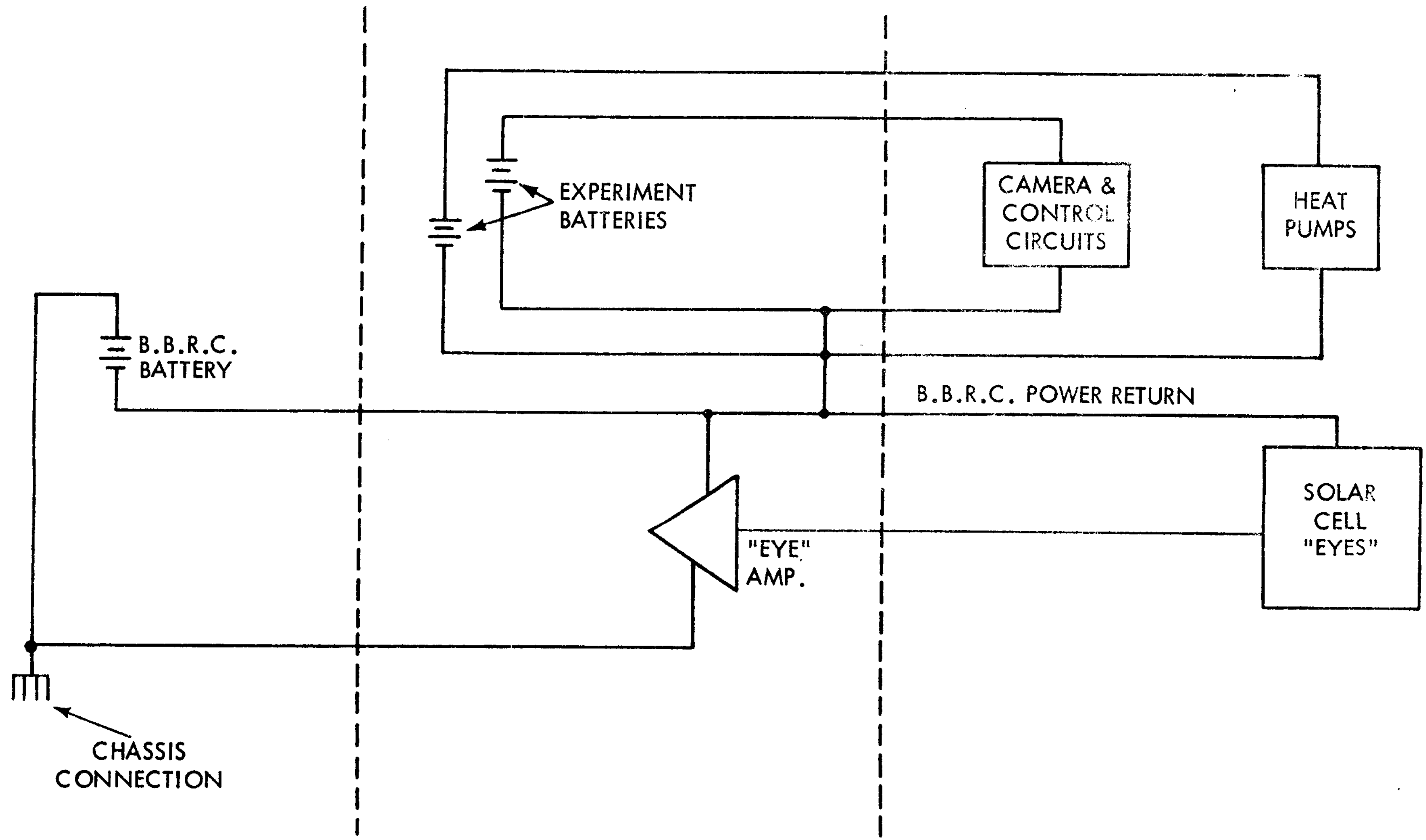
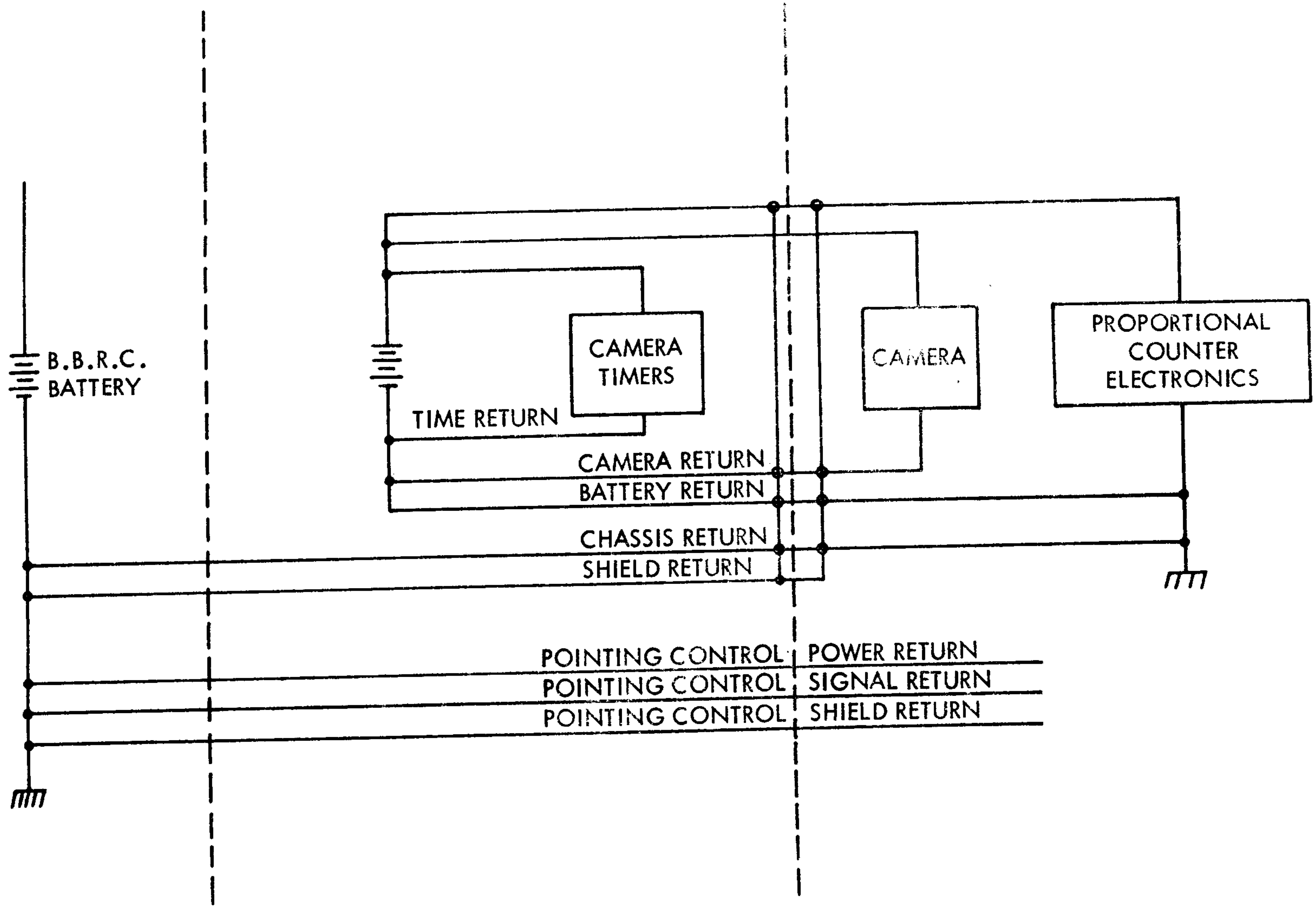
DENOTES CHASSIS

Figure 1



NOTES:
1. DASHED LINES DENOTE DIFFERENT COMPARTMENTS IN THE POINTING CONTROL.
2. CAMERA CURRENT IS OF THE ORDER OF 1 AMP. WITH WHITE NOISE ON THE ORDER OF 40 VOLTS.
3. HEAT PUMP CURRENT IS 2.5 AMPS., PULSING.

Figure 2



NOTES:
1. DENOTES CHASSIS CONNECTION
2. DOTTED LINES DIFFERENT COMPARTMENTS IN THE POINTING CONTROL

Figure 3